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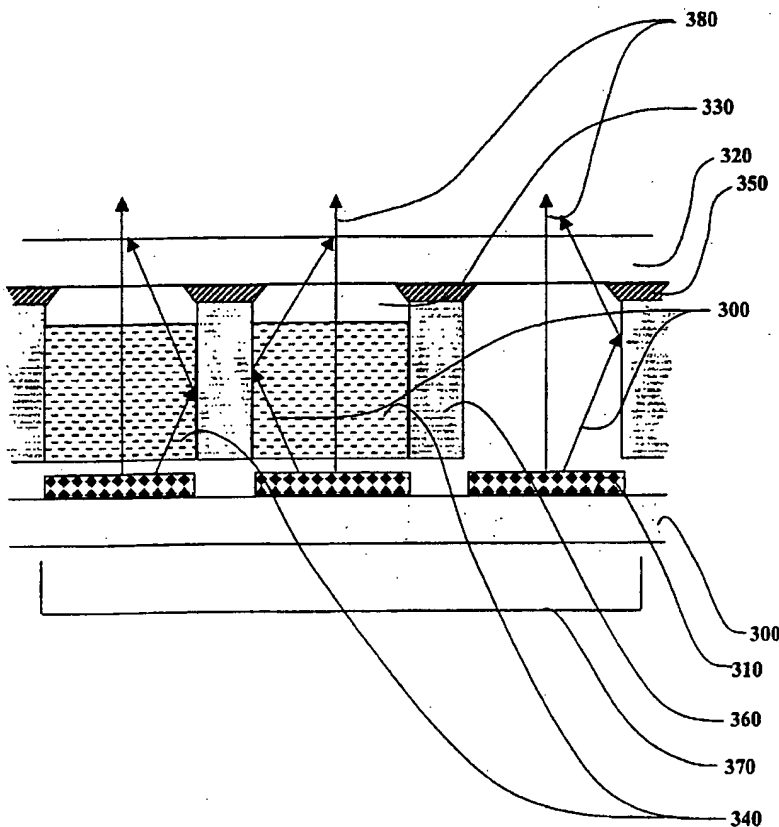
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(54) Title: **ORGANIC LIGHT EMITTING DIODE DISPLAY DEVICES HAVING BARRIER STRUCTURES BETWEEN SUB-PIXELS**



(57) Abstract: The present invention relates to color organic light emitting diode (OLED) display devices having reduced color cross-talk between sub-pixels. Specifically, the present invention relates to color OLED display devices having a reflective barrier structure between adjacent color changing materials and/or color filters. The reflective barrier structure reduces color cross-talk effects by reflecting stray light into the color filter and/or color materials and toward the viewer. The present invention further relates to a method of fabricating an OLED display device having reduced color cross-talk between sub-pixels.

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## TITLE OF THE INVENTION

5       **ORGANIC LIGHT EMITTING DIODE DISPLAY DEVICES HAVING**  
          **BARRIER STRUCTURES BETWEEN SUB-PIXELS**

## CROSS-REFERENCE TO RELATED APPLICATIONS

          This application claims priority on Provisional Patent Application No.  
10   60/225,403, filed August 15, 2000.

          STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR  
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Not applicable.

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## BACKGROUND OF THE INVENTION

          Organic light emitting diode devices ("OLEDs") have been known for  
approximately two decades. All OLEDs work on the same general principles. One or  
more layers of semiconducting organic material is sandwiched between two  
20   electrodes. An electric current is applied to the device, causing negatively charged  
electrons to move into the organic material(s) from the cathode. Positive charges,  
typically referred to as holes, move into the organic material(s) from the anode. The  
positive and negative charges meet in the emitter layer, combine, and produce  
photons. The wavelength of the photons, and consequently the color of emitted light,  
25   depends on the electronic properties of the organic material in which the photons are  
generated.

          OLEDs have a number of desirable characteristics for use in display devices.  
These include a low activation voltage (about 5 volts), fast response when formed  
with a thin emitter layer, and high brightness in proportion to the injected electric  
30   current. OLEDs are currently the subject of aggressive investigative efforts.

          OLED displays are typically composed of a two-dimensional matrix of pixels,  
each of which comprises at least one OLED. Such displays generally include an  
addressing circuit for activating the matrix of pixels in either an active or a passive  
manner.

An OLED display may be monochromatic, that is, each pixel comprising the display emits light of the same color. Alternatively, various pixels of an OLED display may emit different colors. A full-color OLED display is formed from an array of pixels comprising a red, a green and a blue sub-pixel. The sub-pixels in any particular pixel can be activated in various combinations to generate an entire spectrum of colors.

The color of light emitted from the OLED device can be controlled by the selection of the organic material in the emitter layer. Specifically, the precise color of light emitted by a particular OLED may be controlled by selection of host material and dopants in the emitter layer. By changing the kinds of organic solids that comprise the emitter layer, many different wavelengths of light may be emitted, ranging from visible blue, to green, yellow, and red.

The color of light emitted from OLED sub-pixels may also be affected by color filters or color changing materials (CCM) that are formed above OLEDs. To maximize contrast and produce the highest possible color purity, it is important that the light emitted through color filters or CCMs be properly directed. In order to direct the light of a particular color and prevent it from propagating through neighboring pixels ("crossover"), an area of black matrix may be used between individual OLEDs. In the display industry, Cathode Ray Tube (CRT) and Liquid Crystal Display (LCD) technologies have long utilized the concept of black matrix. The black matrix blocks errant propagation of light from a particular sub-pixel to prevent such light from mixing with another color emitted from a neighboring sub-pixel.

Fabrication of full-color microdisplay devices using color filters and CCMs presents many challenges. Color filters and CCMs are typically patterned by wet processing techniques. Because OLEDs are sensitive to moisture, color filters and CCMs are preferably patterned on a separate substrate and then aligned on a matrix of OLED sub-pixels. In order to generate a high-resolution OLED microdisplay, the alignment must be accomplished with high precision (e.g., to about 0.5  $\mu\text{m}$  accuracy). In addition, the gap between the two substrates is preferably minimized (e.g., to about 0.2  $\mu\text{m}$  or less) to avoid color cross-talk between the sub-pixels, especially because the OLED device emission is Lambertian. Furthermore, the two substrates are preferably substantially parallel to each other in order to avoid undesirable effects

such as Newton's rings. Further, the CCM materials can be several micrometers thick, which may also contribute to color cross-talk between sub-pixels.

There is clearly a need for devices with reduced color cross-talk between sub-pixels and for methods of fabricating such devices.

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## BRIEF SUMMARY OF THE INVENTION

The present invention relates to color organic light emitting diode (OLED) displays. In particular, the present invention is directed to an OLED display device having barrier structures around the color sub-pixels that reduce color cross-talk effects. In one embodiment, a substrate comprises both color filter and CCM materials patterned to the desired resolution. The space between the CCM materials over adjacent sub-pixels is filled with black matrix material in order to avoid stray reflections and is also provided with a layer of reflective metal that confines light emission to the desired sub-pixel. The reflective metal barrier structure blocks emission of undesirable color cross-talk and also serves to reflect stray emitted light toward the viewer. The present invention is also directed to a method of fabricating such devices.

The color display devices of the present invention are innovative, simple, and economical. The OLED display devices of the present invention are more efficient, have reduced color cross-talk effects, and have improved color purity and color contrast. In addition, the devices of the present invention have reduced light loss and an increased viewing angle.

Because of the reduced light loss in the OLED display devices of the present invention, relatively thick CCM material layers that efficiently convert blue light to green or red light, but that have low extinction coefficients, can be used.

In a first embodiment, the present invention relates to an OLED display device comprising: (a) a first substrate having a first OLED and a second OLED formed thereon; (b) a first color filter formed on a second substrate and aligned over the first OLED and a second color filter formed on the second substrate and aligned over the second OLED; (c) a patterned black matrix material between the first color filter and the second color filter; (d) a first color-changing material (CCM) having an upper surface adjacent to and formed on the first color filter and a lower surface opposite the

upper surface and a second CCM having an upper surface adjacent to and formed on the second color filter and a lower surface opposite the upper surface; and (e) a barrier structure formed on the patterned black matrix material and surrounding the first CCM and the second CCM and extending from the patterned black matrix material to the lower surfaces of the first and second CCM, but not covering the upper or lower surface of the CCMs, wherein the first OLED and the second OLED are adjacent to each other.

In a second embodiment, the present invention relates to the OLED display device described above, further comprising: (f) a third OLED formed on the first substrate and adjacent to the second OLED; (g) a patterned black matrix material adjacent to the second color filter aligned over the second OLED; and (h) a barrier structure formed on the patterned black matrix material adjacent to the second color filter and extending from the patterned black matrix material to the lower surface of the second CCM and surrounding the CCM on at least one side but not covering the upper or lower surface.

In a third embodiment, the present invention relates to a microdisplay device comprising: (a) a first substrate having a first OLED and a second OLED formed thereon; (b) a first color filter formed on a second substrate and aligned over the first OLED and a second color filter formed on the second substrate and aligned over the second OLED; (c) a patterned black matrix material between the first color filter and the second color filter; (d) a first CCM having an upper surface adjacent to and formed on the first color filter and a lower surface opposite the upper surface, and a second CCM having an upper surface adjacent to and formed on the second color filter and a lower surface opposite the upper surface; and (e) a barrier structure formed on the patterned black matrix material and surrounding the first CCM and the second CCM and extending from the black matrix material to the lower surfaces of the first and second CCM, but not covering the upper or lower surface of the CCMs, wherein the first OLED and the second OLED are adjacent to each other.

In a fourth embodiment, the present invention relates to the microdisplay device described above, and further comprising: (f) a third OLED formed on the first substrate and adjacent to the second OLED; (g) a patterned black matrix material adjacent to the second color filter aligned over the second OLED; and (h) a barrier structure formed on the patterned black matrix material adjacent to the second color

filter and extending from the patterned black matrix material to the lower surface of the second CCM and surrounding the CCM on at least one side but not covering the upper or lower surface.

In a fifth embodiment, the present invention relates to an OLED display device comprising: (a) a first substrate having an OLED formed thereon; (b) a color filter formed on a second substrate and aligned over the OLED; (c) a patterned black matrix material formed on the second substrate and adjacent to the color filter on at least one side; (d) a CCM having an upper surface adjacent to and formed on the color filter and a lower surface opposite the upper surface; and (e) a barrier structure formed on the patterned black matrix material and extending from the patterned black matrix material to the lower surface of the CCM and surrounding the CCM on at least one side but not covering the upper or lower surface.

In a sixth embodiment, the present invention relates to a method of fabricating an OLED display device, comprising the steps of: (a) forming a patterned black matrix material layer on a first substrate such that the black matrix material layer is patterned into lines; (b) forming a patterned color filter layer on the first substrate such that the patterned color filter material is adjacent to and surrounded by the patterned black matrix material on the substrate; (c) forming a patterned CCM layer on the color filter layer; (d) forming a barrier structure on the patterned black matrix material; and (e) aligning the first substrate with a second substrate having formed thereon at least one OLED.

In a seventh embodiment, the present invention relates to a method of fabricating an OLED display device, comprising the steps of: (a) forming a patterned black matrix material layer on a first substrate such that the black matrix material layer is patterned into lines; (b) forming a patterned color filter layer on the first substrate such that the patterned color filter material is adjacent to and surrounded by the patterned black matrix material on the first substrate; (c) forming a patterned CCM layer on the color filter layer; (d) forming a barrier structure on the patterned black matrix material; and (e) aligning the first substrate with a second substrate having formed thereon at least one OLED, wherein the barrier structure comprises nickel and has an aspect ratio of about 10 to 1, and wherein the step of forming a barrier structure is done by electro-plating at room temperature in a solution comprising  $\text{NiSO}_4$ ,  $\text{MgSO}_4$ ,  $\text{NaCl}$ , and  $\text{H}_3\text{BO}_3$  and having a pH of about 5.6, using a

nickel electrode that is about two times larger in surface area than said first substrate at an electric field strength of about 1 to about 5 volt/cm and a current density of between about 10 and about 100 mA/cm<sup>2</sup>.

5 In an eighth embodiment, the present invention relates to a method of fabricating an OLED display device, comprising the step of aligning a first substrate having formed thereon a patterned color filter layer and a patterned black matrix material with a second substrate having formed thereon at least one OLED, wherein the patterned black matrix material layer is patterned into lines and the patterned color filter material is adjacent to and surrounded by the patterned black matrix material on  
10 the first substrate, wherein a patterned CCM layer is formed on the patterned color filter layer, and wherein a barrier structure is formed on the patterned black matrix material.

In a ninth embodiment, the present invention relates to an improvement in a color OLED display device emitting light through a top substrate and having a bottom  
15 substrate, a plurality of OLED stacks for emitting the light disposed on the bottom substrate, and means aligned with the OLED stacks for changing the color of the light, the improvement comprising means for directing the light through the color changing means.

In a tenth embodiment, the present invention relates to a method of forming a  
20 color OLED display device having a plurality of OLED stacks, comprising the steps of: (a) forming a bottom substrate; (b) forming a plurality of electrodes on the bottom substrate; (c) forming an OLED stack on each of the plurality of electrodes; (d) forming a black matrix layer on a top substrate; (e) forming a layer for color changing on the top substrate; (f) forming a light directing layer on the black matrix layer; (g)  
25 aligning the top substrate precisely with and parallel to the bottom substrate; and (h) sealing the top substrate to the bottom substrate.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

Figure 1 shows a prior art OLED device.

30 Figure 2 shows an OLED device having reflective barrier materials around each sub-pixel.



Figure 3 shows a full-color OLED display device according to the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

5 "Bottom electrode," as used herein, means an electrode that is deposited directly onto the substrate.

"Top electrode," as used herein, means an electrode that is deposited at the end of the OLED that is distal to the substrate.

10 "Hole-injection layer," as used herein, is a layer into which holes are injected from an anode when a voltage is applied across an OLED.

"Hole-transport layer," as used herein, is a layer having high hole mobility and high affinity for holes that is between the anode and the emitter layer. It will be evident to those of skill in the art that the hole-injection layer and the hole-transport layer can be a single layer ("hole-injection/hole-transport layer"), or they can be  
15 distinct layers comprising different chemical compounds.

"Electron-injection layer," as used herein, is a layer into which electrons are injected from a cathode when a voltage is applied across an OLED.

"Electron-transport layer," as used herein, is a layer having high electron mobility and high affinity for electrons that is between the cathode and the emitter layer. It will be  
20 evident to those of skill in the art that the electron-injection layer and the electron-transport layer can be a single layer ("electron-injection/electron-transport layer"), or they can be distinct layers comprising different chemical compounds.

"Down-emitting," as used herein, refers to an OLED in which light is transmitted through the transparent or semi-transparent bottom electrode, which is  
25 typically an anode.

"Up-emitting," as used herein, refers to an OLED in which light is transmitted through the transparent or semi-transparent top electrode, which is typically a cathode.

A prior art OLED is shown in Figure 1. The OLED comprises a bottom  
30 substrate 100 with an OLED stack 110 disposed thereon. The OLED further comprises a top substrate 120 having a color filter 130, color changing material 140, and black matrix material 150 formed thereon. The top substrate 120 and the bottom

substrate 100 are precisely aligned and parallel to each other before the OLED is sealed. Light 180, 190 is emitted from the emitter layer of the OLED stack 110. Some of the light 170 passes through the CCM 140 and the color filter 130 in the preferred direction for maximum brightness and color purity and emerges through the top substrate 120. Some of the light 190 is emitted from the OLED stack 110 at undesirable angles, which results in color cross-talk with neighboring sub-pixels (not shown).

The OLED shown in Figure 1 operates as follows. The OLED stack 110 emits light upon activation of the cathode line and anode line (not shown) to which it is connected. The anode may be a bottom electrode or a top electrode. The cathode may be a top electrode or a bottom electrode. The emitted light may be of a particular color, or may be white, depending on the organic material in the emitter layer of the organic stack 110. The color of the emitted light may be changed upon passing through CCMs 140 and color filter 130. The color filter typically absorbs light emitted from the underlying organic stack 110 that passes through the CCM 140 unconverted. The preferred direction of emitted light is depicted by arrow 170, but light may be emitted from the organic stack 110 at other angles, depicted as arrow 190, such that it is emitted as stray light of undesirable colors, resulting in color cross-talk. Black matrix material 150 may be provided on the top substrate 120 to reduce the cross-talk of the emitted light. Emitted light 190 that does not pass through the CCM 140 and color filter 130 contributes to color purity loss and poor contrast in the resulting visual display.

One sub-pixel of an embodiment of the present invention is shown in Figure 2. As embodied herein, the OLED display device comprises a bottom substrate 200 having an OLED stack 210 disposed thereon. The device further comprises additional sub-pixels (not shown) that are adjacent to the sub-pixel that is shown. The device further comprises a top substrate 220 having color filters 230 that filter out unconverted light emitted from the underlying OLED stack 210, CCMs 240, and black matrix material 250 formed thereon.

The device further comprises a barrier structure 260 disposed on the black matrix material 250 which surrounds the sides of the color filter 230 and CCM 240. The barrier structure 260 may be electro-plated on the black matrix 250. The barrier structure 260 may be a layer of metal, for example nickel, which typically highly

reflects visible light. This electro-plated nickel barrier structure 260 may be deposited with a very high aspect ratio, filling up the space around the high resolution CCM 240 and color filter 230.

5 The top substrate 220 and bottom substrate 200 are precisely aligned and are preferably parallel to each other before the OLED is sealed. Some light 270 is emitted through the CCM 240 and the color filter 230 in the preferred direction for maximum brightness and color purity. Some light 280 is emitted from the OLED stack 210 at undesirable angles (stray light), hits the barrier material 260 and is reflected so that it passes through the CCM 240 and the color filter 230 and emerges  
10 through the top substrate 220.

Thus, the barrier structure 260 virtually eliminates color cross-talk effects. Moreover, the high reflectivity of the barrier material 260 allows the rays of light 280 that strike the barrier at an angle to emerge from the display structure towards the viewer, thereby reducing light loss and increasing viewing angle. The vertical design  
15 of the barrier structure 260 allows CCM materials with low extinction coefficient but efficient conversion from blue light to red light and to green light to be used in OLED and other displays. As embodied herein, OLED display devices with barrier structures maximize the brightness, color contrast and color purity of emitted light.

In a typical matrix-addressed OLED display, numerous OLED stacks are  
20 formed on a single substrate and arranged in groups in a regular grid pattern. Several OLED groups forming a column of the grid may share a common cathode, or cathode line. Several OLED groups forming a row of the grid may share a common anode, or anode line. The individual OLEDs in a given group emit light when the cathode line and the anode line are activated at the same time.

25 A full-color OLED display device of the present invention is shown in Figure 3. As embodied herein, the full-color OLED display device comprises a bottom substrate 300 having OLED stacks 310 disposed thereon. The device further comprises a top substrate 320 having color filters 330 that filter out unconverted light emitted from the underlying OLED stacks 310, CCMs 340, and black matrix material  
30 350 formed thereon.

The device further comprises a barrier structure 360 disposed on the black matrix material 350 and which extends around the color filters 330 and CCMs 340.

The barrier structure 360 is preferably electro-plated on the black matrix 350 and may be a layer of metal, for example nickel, which typically highly reflects visible light. The electro-plated barrier structure 360 may be deposited with a very high aspect ratio, filling up the spaces around the high resolution CCMs 340 and color filters 330.

5           The top substrate 320 and bottom substrate 300 are precisely aligned preferably using registration marks and are preferably parallel to each other before the OLED display device is sealed.

          The OLED stacks 310 preferably all emit blue light. A sub-pixel having no color filter or CCM is therefore a blue sub-pixel, and a sub-pixel having a CCM 340  
10   and color filter 330 aligned over it is a red sub-pixel if it has a blue-to-red CCM 340 aligned over it, or a green sub-pixel if it has a blue-to-green CCM 340 aligned over it. The adjacent red, green and blue sub-pixels form a pixel 370 of the full-color display.

          Some light 380 is emitted through the CCMs 340 and the color filter 330 in the preferred direction for maximum brightness and color purity. Other light 390 is  
15   emitted from OLED stacks 310 at undesirable angles (stray light), hits the barrier material 360 and is reflected in a more preferable direction so that it passes through the CCM 340 or the color filter 330 and emerges through the top substrate 320.

          Although the embodiments of the present invention described above are up-emitting devices, it will be readily appreciated by one skilled in the art that the present  
20   invention also encompasses down-emitting devices.

          Although the embodiment shown in Figure 3 has no color filter over the blue sub-pixel and color filters over the blue-to-red and blue-to-green CCMs that absorb unconverted light emitted from the underlying OLED stacks, it will be evident to one of skill in the art that additional filters may be placed over any sub-pixel in order to  
25   adjust the wavelength of light emitted through the substrate. For example, if blue light emitted from the underlying OLED stack is not close to the desired CIE coordinate, then a filter may be placed over the blue sub-pixel in order to adjust the wavelength. Furthermore, if either the red or green light emitted from the CCMs is not close to the desired CIE coordinate for red or green light, respectively, an  
30   additional notch filter that only transmits light close to the desired CIE coordinate may be used over these sub-pixels.

A substrate may be made from any material known in the art, including glass, silicon, plastic, quartz and sapphire. If the OLED display is formed on a silicon chip, the chip preferably includes drive electronics and one of the sub-pixel electrodes. The top electrode may be common to all sub-pixels.

5 In a typical OLED, one of the electrodes is transparent. The cathode is typically constructed of a low work function material. The anode is typically constructed of a high work function material. Between the anode and the cathode is the electroluminescent medium, which comprises at least one organic layer. The at least one organic layer may be a hole-injection/hole-transport layer adjacent to the  
10 anode, an electron-injection/electron-transport layer adjacent to the cathode, or an emitter layer. Typically, OLED devices operate with a DC bias of from 2 to 30 volts.

OLEDs can be fabricated by any method known in the art. The OLED layers may be formed by evaporation, spin casting, self-assembly or other appropriate film-forming techniques. Thicknesses of the layers typically range from a few monolayers  
15 to about 2,000 Angstroms. In one embodiment, OLEDs are formed by vapor deposition of each layer. In a preferred embodiment, OLEDs are formed by thermal vacuum vapor deposition.

OLEDs typically work best when operated in a current mode. The light output is more stable for constant current drive than for a constant voltage drive. This is in  
20 contrast to many other display technologies, which are typically operated in a voltage mode. An active matrix display using OLED technology, therefore, requires a specific pixel architecture to allow for a current mode of operation.

CCMs and color filters can be deposited by any method known in the art, including spin-coating, meniscus-coating, spray-coating, dip-coating, blade-coating,  
25 from solution or suspension or by sublimation in a vacuum. CCMs and color filters may be patterned by any method known in the art, including, but not limited to, photo-oxidation and photolithography.

Black matrix material includes, but is not limited to, a metal such as chromium, molybdenum and aluminum, carbon black, and a mixture of chromium  
30 and silicon oxide. Black matrix material may be patterned by any method known in the art, including, but not limited to, photolithography and e-beam evaporation.

"Patterning," as used herein, means that the materials are formed into stripes, squares, rectangles, triangles, hexagons, circles, or any other shape known in the art. Preferably, each individual OLED is rectangular and the color changing materials are patterned in parallel stripes, or rectangular dots. The patterning of color changing materials and color filters provides for the formation of discrete red, green and blue sub-pixels.

In a preferred embodiment, an array of OLEDs of the present invention comprise a microdisplay. A microdisplay is a display device that is not viewable by the unaided eye, and therefore requires the use of an optic. A microdisplay may be monochromatic, that is, each pixel comprising the display emits light of the same color. Alternatively, various pixels of a microdisplay may emit different colors. A full-color microdisplay is formed from an array of pixels comprising a red, a green and a blue sub-pixel. The sub-pixels in any particular pixel can be activated in various combinations to generate an entire spectrum of colors. Preferably, the sub-pixel size of a microdisplay device is less than about 15 microns, more preferably less than about 5 microns, and most preferably between about 2 microns and about 3 microns.

## EXAMPLES

### EXAMPLE 1: FABRICATION OF AN OLED DISPLAY DEVICE HAVING BARRIER MATERIAL BETWEEN ADJACENT SUB-PIXELS

An OLED display device of the present invention is fabricated as follows. A first substrate is prepared by depositing a black matrix material onto the substrate and then patterning it into a plurality of intersecting lines to form a grid pattern. The lines are formed so that an electrical contact can be made on each line or on the matrix as a whole. The black matrix material is a mixture of about 60% Cr and 40% SiO. The thickness of the black matrix layer may be from about 2000 Å to about 4000 Å.

Patterning of the black matrix material is done by e-beam evaporation.

Color filter material is deposited on the substrate and patterned such that the grid of black matrix material lines is adjacent to and surrounds the patterned color filter material. CCMs are then deposited on the color filter material and patterned.

An electro-plating solution comprising  $\text{NiSO}_4$  (125 g),  $\text{MgSO}_4$  (50 g),  $\text{NaCl}$  (2 g), and  $\text{H}_3\text{BO}_3$  (12.5 g) in 500 mL water at pH 5.6 is prepared and filtered. In order to increase the aspect ratio of the barrier material, an ionic surfactant may be added to the solution. The substrate comprising patterned black matrix, CCMs and color filters is immersed in the electro-plating solution at room temperature. Electro-plating is done using a nickel electrode that is typically two times larger in surface area than the substrate at an electric field strength of about 1-5 volt/cm and a current density between about 10-100 mA/cm<sup>2</sup>.

Under these conditions, columns of barrier material having an aspect ratio of up to about 10:1 (length:width) are deposited between adjacent patterned CCMs and color filters.

An array of OLEDs are formed on a second substrate by any method known in the art. The first and second substrates are aligned by any method known in the art, preferably using registration marks, and sealed to form the OLED display device.

## CLAIMS:

1. An OLED display device comprising:

(a) a first substrate having a first OLED and a second OLED formed thereon;

5 (b) a first color filter formed on a second substrate and aligned over the first OLED and a second color filter formed on the second substrate and aligned over the second OLED;

(c) a patterned black matrix material between said first color filter and said second color filter;

10 (d) a first color-changing material (CCM) having an upper surface adjacent to and formed on the first color filter and a lower surface opposite said upper surface and a second CCM having an upper surface adjacent to and formed on the second color filter and a lower surface opposite said upper surface; and

(e) a barrier structure formed on the patterned black matrix material and surrounding said first CCM and said second CCM and extending from said patterned black matrix material to said lower surfaces of said first and second CCM, but not covering said upper or lower surface of said CCMs,

15 wherein said first OLED and said second OLED are adjacent to each other.

2. The OLED display device of claim 1, further comprising:

20 (f) a third OLED formed on the first substrate and adjacent to said second OLED;

(g) a patterned black matrix material adjacent to said second color filter aligned over said second OLED; and

25 (h) a barrier structure formed on the patterned black matrix material adjacent to said second color filter and extending from said patterned black matrix material to said lower surface of said second CCM and surrounding said CCM on at least one side but not covering said upper or lower surface.

3. The device of claim 1, wherein the barrier structure comprises nickel.

4. The device of claim 1, wherein the aspect ratio of the barrier structure  
30 is about 10 to 1.



5. The device of claim 2, wherein said first, second and third OLEDs emit blue light, said first patterned color filter and said second patterned color filter are blue light filters, said first patterned color-changing material is a blue-to-green color changing material, and said second patterned color-changing material is a blue-to-red color changing material.

6. A microdisplay device comprising:

- (a) a first substrate having a first OLED and a second OLED formed thereon;
- (b) a first color filter formed on a second substrate and aligned over the first OLED and a second color filter formed on the second substrate and aligned over the second OLED;
- (c) a patterned black matrix material between said first color filter and said second color filter;
- (d) a first CCM having an upper surface adjacent to and formed on the first color filter and a lower surface opposite said upper surface, and a second CCM having an upper surface adjacent to and formed on the second color filter and a lower surface opposite said upper surface; and
- (e) a barrier structure formed on the patterned black matrix material and surrounding said first CCM and said second CCM and extending from said black matrix material to said lower surfaces of said first and second CCM, but not covering said upper or lower surface of said CCMs,

wherein said first OLED and said second OLED are adjacent to each other.

7. The microdisplay device of claim 6, further comprising:

- (f) a third OLED formed on the first substrate and adjacent to said second OLED;
- (g) a patterned black matrix material adjacent to said second color filter aligned over said second OLED; and
- (h) a barrier structure formed on the patterned black matrix material adjacent to said second color filter and extending from said patterned black

matrix material to said lower surface of said second CCM and surrounding said CCM on at least one side but not covering said upper or lower surface.

8. An OLED display device comprising:

(a) a first substrate having an OLED formed thereon;

5 (b) a color filter formed on a second substrate and aligned over the OLED;

(c) a patterned black matrix material formed on the second substrate and adjacent to the color filter on at least one side;

10 (d) a CCM having an upper surface adjacent to and formed on the color filter and a lower surface opposite said upper surface; and

(e) a barrier structure formed on the patterned black matrix material and extending from said patterned black matrix material to said lower surface of said CCM and surrounding said CCM on at least one side but not covering said upper or lower surface.

15 9. A method of fabricating an OLED display device, comprising the steps of:

(a) forming a patterned black matrix material layer on a first substrate such that the black matrix material layer is patterned into lines;

20 (b) forming a patterned color filter layer on said first substrate such that the patterned color filter material is adjacent to and surrounded by the patterned black matrix material on the substrate;

(c) forming a patterned CCM layer on said color filter layer;

(d) forming a barrier structure on said patterned black matrix material; and

25 (e) aligning said first substrate with a second substrate having formed thereon at least one OLED.

10. The method of claim 9, wherein said step of forming a barrier structure is done by electro-plating.

11. The method of claim 10, wherein the aspect ratio of said barrier structure is about 10 to 1.

12. A method of fabricating an OLED display device, comprising the steps of:

(a) forming a patterned black matrix material layer on a first substrate such that the black matrix material layer is patterned into lines;

5 (b) forming a patterned color filter layer on said first substrate such that the patterned color filter material is adjacent to and surrounded by the patterned black matrix material on the first substrate;

(c) forming a patterned CCM layer on said color filter layer;

(d) forming a barrier structure on said patterned black matrix material; and

10 (e) aligning said first substrate with a second substrate having formed thereon at least one OLED,

wherein said barrier structure comprises nickel and has an aspect ratio of about 10 to 1, and

wherein the step of forming a barrier structure is done by electro-plating at  
15 room temperature in a solution comprising  $\text{NiSO}_4$ ,  $\text{MgSO}_4$ ,  $\text{NaCl}$ , and  $\text{H}_3\text{BO}_3$  and having a pH of about 5.6, using a nickel electrode that is about two times larger in surface area than said first substrate at an electric field strength of about 1 to about 5 volt/cm and a current density of between about 10 and about 100 mA/cm<sup>2</sup>.

20 13. A method of fabricating an OLED display device, comprising the step of:

aligning a first substrate having formed thereon a patterned color filter layer and a patterned black matrix material with a second substrate having formed thereon at least one OLED,

25 wherein the patterned black matrix material layer is patterned into lines and the patterned color filter material is adjacent to and surrounded by the patterned black matrix material on the first substrate, wherein a patterned CCM layer is formed on the patterned color filter layer, and wherein a barrier structure is formed on the patterned black matrix material.

30 14. The method of claim 13, wherein said barrier structure is formed on the black matrix material by electro-plating.

15. The method of claim 14, wherein the aspect ratio of said barrier structure is about 10 to 1.

16. In a color OLED display device emitting light through a top substrate and having a bottom substrate, a plurality of OLED stacks for emitting said light  
5 disposed on said bottom substrate, and means aligned with said OLED stacks for changing the color of said light, the improvement comprising:

means for directing said light through said color changing means.

17. The device of claim 16, wherein each of said plurality of OLED stacks further comprises a first color sub-pixel and a second color sub-pixel.

10 18. The device of claim 17, wherein a layer of black matrix is formed on said top substrate.

19. The device of claim 18, wherein said directing means is formed on said black matrix.

15 20. The device of claim 19, wherein said directing means is formed around each of said first color sub-pixel and said second color sub-pixel.

21. The device of claim 20, wherein said directing means further comprises a layer of reflective metal.

22. The device of claim 21, wherein said reflective metal is nickel.

20 23. The device of claim 22, wherein said metal layer is formed on said black matrix by electro-plating.

24. A method of forming a color OLED display device having a plurality of OLED stacks, comprising the steps of:

- (a) forming a bottom substrate;
- (b) forming a plurality of electrodes on said bottom substrate;
- 25 (c) forming an OLED stack on each of said plurality of electrodes;
- (d) forming a black matrix layer on a top substrate;
- (e) forming a layer for color changing on said top substrate;
- (f) forming a light directing layer on said black matrix layer;

(g) aligning said top substrate precisely with and parallel to said bottom substrate; and

(h) sealing said top substrate to said bottom substrate.

25. The method of claim 24, wherein the step of forming said layer for  
5 color changing further comprises the steps of:

(a) forming a color filter layer on said top substrate; and

(b) forming a color changing material layer on said color filter layer.

26. The method of claim 25, wherein each of said plurality of OLED  
stacks further comprises a first color sub-pixel and a second color sub-pixel.

10 27. The method of claim 26, wherein said light directing layer is formed  
around said first color sub-pixel and said second color sub-pixel.

28. The method of claim 27, wherein said light directing layer is formed  
on said black matrix layer by electro-plating.

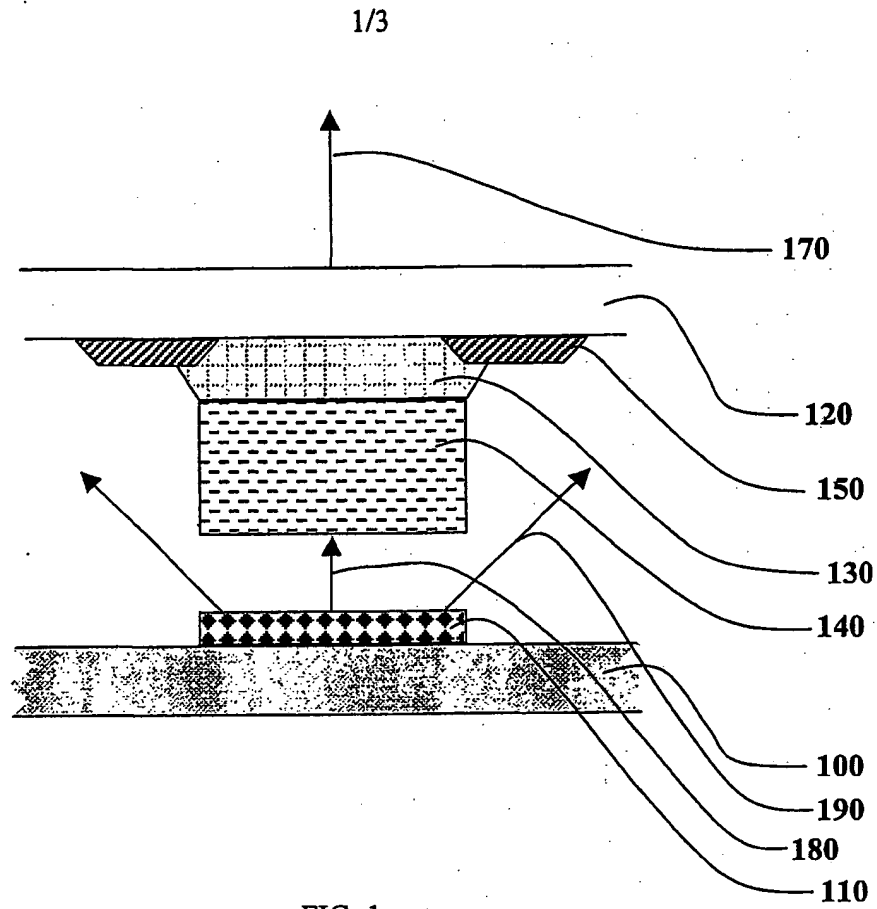


FIG. 1  
Prior Art

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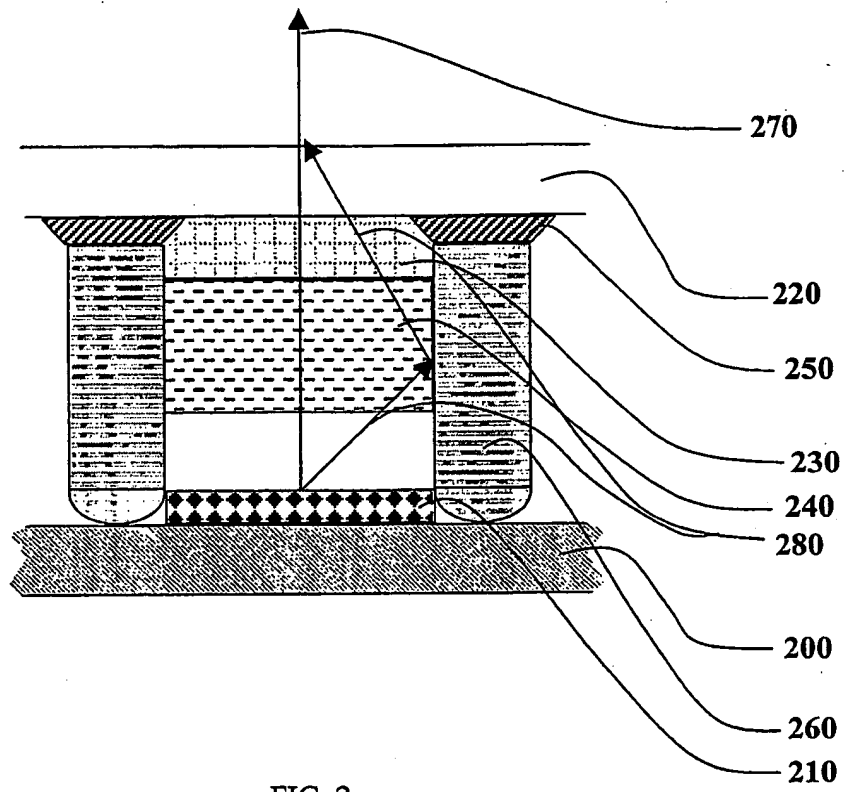


FIG. 2

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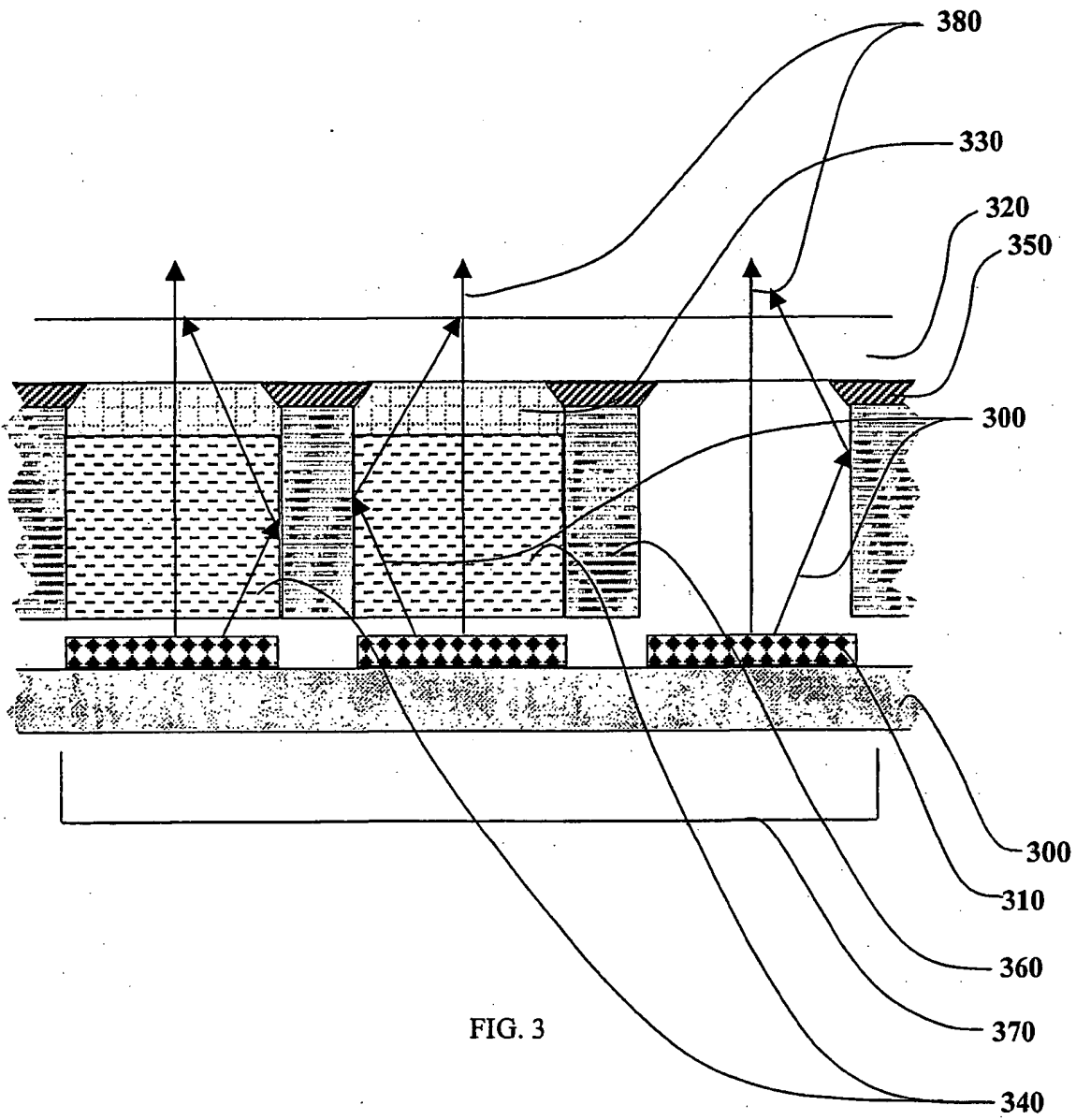


FIG. 3



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